041-060.fm Page 41 Tuesday, February 17, 2004 11:40 AM

NEUROPSYCHOLOGICAL REHABILITATION, 2004, *14* (1/2), 41–60

Technological memory aids for people with memory deficits

Narinder Kapur
Addenbrooke's Hospital, Cambridge, UK

Elizabeth L. Glisky
University of Arizona, Tuscon, USA

Barbara A. Wilson
MRC Cognition and Brain Sciences Unit, Cambridge, UK

This paper reviews the application of external memory aids and computer-based procedures for the enhancement of memory functioning in neurological patients particularly adults with non-progressive brain injury and those with mild/moderate memory deficits. Memory aids may function as event memory aids to improve prospective memory functioning (Herrmann et al., 1999), or as knowledge memory aids to facilitate the acquisition and utilisation of factual information. We review the range of available external memory aids and evidence on their efficacy in clinical settings. Several studies have shown that external memory aids act as effective reminders and improve prospective memory functioning. Computer-based resources and procedures for improving memory functioning include those that serve similar functions to external memory aids, those which present memory tasks as memory retraining exercises, those which instruct the individual in the use of memory strategies,

Correspondence should be addressed to Professor N. Kapur, Neurosciences Unit, Box 83, Addenbrooke's Hospital, Hills Road, Cambridge, CB2 2QQ. Tel: 01223 216040, Fax: 01223 217909. Email: n.kapur@soton.ac.uk

A version of this paper appeared in Kapur, N., Glisky, E. L., & Wilson, B. A. (2002). External memory aids and computers in memory rehabilitation. In A. D. Baddeley, M. Kopelman, & B. A. Wilson (Eds.), *Handbook of memory disorders* (2nd ed.). Chichester, UK: John Wiley. Reproduced with permission.

© 2004 Psychology Press Ltd
http://www.tandf.co.uk/journals/pp/09602011.html DOI:10.1080/09602010343000138

041-060.fm Page 42 Tuesday, February 17, 2004 11:40 AM

those which directly assist in domain-specific knowledge acquisition, and those which form the basis of "virtual reality" memory rehabilitation procedures. While there may be potential for computer-based procedures, there is at present only limited evidence on their efficacy and cost-effectiveness. We outline practical issues relating to the implementation of memory aids in clinical settings. We consider future developments that may impact on the application of external memory aids and computers in the treatment of human memory disorder.

INTRODUCTION

At present, compared to conceptual frameworks that exist for considering errors in attention and memory (Reason, 1990; Schacter, 2001), or for viewing compensation strategies by memory impaired individuals (Wilson & Watson, 1996), there is no widely accepted conceptual framework for considering the functional application of memory aids in neurological rehabilitation, although some preliminary attempts have been made in specific settings, such as the use of memory aids in office environments (Reason, 2002).

In this paper, we consider mechanical (for example, pill boxes and kitchen timers), and electronic aids, together with computer-based resources. Although environmental and stationery aids are helpful and widely used in memory rehabilitation, these are not considered in detail here as we are focusing on technological memory aids in the rehabilitation of memory impaired people, particularly adults with non-progressive brain injury such as traumatic brain injury, encephalitis and hypoxia. We are not dealing with people with very severe amnesia or with dementia. The interested reader is referred to Kapur, Glisky, and Wilson, (2002). Some of the beneficial effects of memory aids can be considered in terms of the long-established distinction between experiential and knowledge memory (Nielsen, 1958), the subsequent distinctions between episodic and semantic memory (Tulving, 1972), and between memory for events and memory for facts (Warrington, 1986). Thus, aids may be used mainly to enhance event memory, or they may be more useful in knowledge acquisition and utilisation. Often, a specific memory aid can serve both purposes, and one function may merge into another.

We review both novel memory aids and also the more obvious ways in which external memory aids may be useful in clinical settings, to allow an overview of devices that can enhance memory functioning in neurological patients, and to enable us to bring the wide range of memory aids within some form of coherent conceptual framework.

041-060.fm Page 43 Tuesday, February 17, 2004 11:40 AM

ELECTRONIC ORGANISERS AND RELATED ELECTRONIC REMINDERS TO ENHANCE EVENT OR PROSPECTIVE MEMORY

The most common commercially available electronic memory aids are electronic organisers. In recent years, these have become more compact, sophisticated and diverse in their functions, and also less expensive. In general, such devices can be useful as memory aids in five main ways:

1. An electronic diary to keep a record of appointments.
2. An alarm which provides auditory cues, with or without a visual ones such as text or pictorial information, at pre-set, regular or irregular times.
3. A temporary store for items such as shopping lists, messages, etc.
4. A more permanent store for information such as addresses, telephone-numbers, etc.
5. In more expensive models, a communication device that can receive and send information such as reminders and factual knowledge.

Electronic organisers range in size from pocket-sized to the size of a wallet/filofax—palmtop devices. Alarms can be set to sound at the same time as a stored message is displayed, and for some models multiple daily, weekly or monthly alarms can be set. Many electronic organisers can be interfaced to enable them to transfer data to computers, and for certain models add-on cards can be bought to store information and allow for specialised applications. Most models have back-up devices to safeguard against loss of stored information. Electronic organisers vary greatly in features which may or may not be applicable to the needs of neurological patients with memory impairment. The following features, drawing upon the basis of our clinical experience and our appreciation of the literature, may help when selecting an electronic organiser for use with memory-impaired people.

General features

The organiser should be compact enough to fit into a shirt pocket or other handy place. Some of the more expensive electronic organisers may be too bulky to be carried around all the time, although they could still be kept in a coat pocket or a briefcase.

Databank watches are available which have many of the functions of electronic organisers. While more compact and easier to carry around, they are more limited because of the fine motor control and visual acuity needed to operate them, they have limited storage capacity, and so forth.

Although batteries may need to be changed only once every few years for watches (more frequently for personal organisers), one needs to consider the motor dexterity involved in changing the battery, and the simplicity of the instructions, in addition to the usual life of the battery and whether there is a back-up battery. Back-up batteries are useful especially where there is a large

041-060.fm Page 44 Tuesday, February 17, 2004 11:40 AM

amount of stored data to be retained in the device's memory. Around 32K memory will usually suffice for most uses. More sophisticated organisers come with removable memory cards.

Patients should not have to consult the manual, but it helps if it is clear and not too intimidating in its length. Summarised forms of information such as "help cards" are useful in that they provide a quick reference to turn to without having to refer to the manual. Those using the organiser as a data gathering device in settings remote from their workplace will find it useful to be able to link up to a personal computer.

The clarity of screen display is important—some of the less expensive organisers have poor displays despite being useful in other ways. Clarity is a critical item for many neurological patients, especially older people who may have reduced visual acuity.

Since electronic organisers are designed for professionals or executives rather than for people with a disability, there are usually keys which are superfluous when the device is used as a memory aid. These may serve as a distraction, especially if the patient has visual search problems, in which case redundant keys can be masked. The keys themselves should be clearly labelled and well laid out, and, if possible, operations should be executed by a single key press rather than by a sequence of keys. Keyboards which provide tone feedback when a key is pressed are desirable.

Voice organisers are available for those who find keyboard entry difficult because of tremor or other movement disorder. These have the same text storage and alarm features as most conventional electronic organisers, but rely on voice input. The device is "trained" to recognise the voice of the user, but even then occasional errors may occur. While current devices are compact, the input keys require a degree of motor control that may be outside the capacity of many neurological patients. (See Gartland, this issue, for further discussion of these factors.)

Storing and retrieving information

There are three basic operations which memory-impaired people need to learn—*entering* information, *reviewing* stored information, and *deleting* information from storage. Check whether these basic operations are simple or complicated for patients. Consider whether word-processing features are useful—for example, if a phrase is entered frequently, can a code rather than the full phrase be entered?

In addition to a prospective memory feature giving an alarm (with or without an associated message), it is useful to have a general memo facility so that items can be stored which need to be done at some time, but not necessarily on a particular day or at a particular time. In less expensive organisers without such a memo facility, the telephone storage facility can be used instead.

041-060.fm Page 45 Tuesday, February 17, 2004 11:40 AM

While all electronic organisers have basic text storage devices that allow for both temporary and permanent stores of knowledge, some now come with the facility to offer advanced storage features such as, navigational information, the ability to store pictorial material such as photographs and the ability to link onto information resources on the internet.

Alarm features

Electronic organisers are useful as reminders in the following settings:

1. Instances where events may occur between thinking about doing something and remembering to do it, e.g., deciding in the morning to buy something later in the day. This is particularly important when intervening activities preoccupy the individual.
2. Situations where a long interval separates thinking about doing something and having to do it, e.g., if one makes an appointment for several months in the future.
3. When there is a high premium on very accurate, precise recall and where internal memory aids may be fallible, e.g., remembering to take a cake from an oven at a specific time.
4. Where multiple alarm reminders are required, e.g., having to take tablets several times a day.

There are essentially two types of alarms, those with and those without a verbal/pictorial message. The major virtue of electronic organisers is their ability to display text when an alarm goes off. Therefore, having an alarm with a simultaneous message display, whether this be verbal or pictorial, is a critical feature. This facility can be used for two main purposes: situations where something has to be done on a particular day and at a specific time, and those situations where it is important that certain things are done but which are not necessarily tied to a particular time.

A number of currently available electronic organisers, mobile phones and other types of personal digital assistants, enable pictorial icons to be used within the context of reminder messages. With some devices, it is also possible for recorded speech to be used as a reminder, instead of visual text or pictorial cues, and such a memory aid has been successfully used in one study with five memory impaired patients who had to remember to pass on a message or carry out specific domestic chores (Van den Broek et al., 2000).

Some organisers emit a warning several minutes before the alarm sounds. For certain activities requiring initial preparation, such as having to go to a meeting, this can be useful.

Alarms that can be set to occur at regular intervals, such as daily, weekly or monthly, may be helpful in contexts where activities need to be carried out repeatedly and at specific times.

041-060.fm Page 46 Tuesday, February 17, 2004 11:40 AM

Turning to research findings with electronic organisers, Azrin and Powell (1969) found that a pill container which sounded a tone at the time medication was to be taken, and which dispensed a tablet at the same time the tone was turned off, was better at inducing patient compliance than a simple alarm timer or a container that made no sound. Fowler, Hart, and Sheehan (1972) used a timer combined with a schedule card to help their patient stick to a daily routine in his rehabilitation programme. Naugle, Naugle, Prevey, and Delaney (1988) worked with a man who consistently forgot to use stationery memory aids such as diaries and log books. They found an "alarm display" watch helped him remember rehabilitation activities. Giles and Shore (1989) used a PSION organiser to help their patient remember to do weekend domestic chores. This was more beneficial than a pocket diary. Kapur (1995) described preliminary data on the use of an electronic organiser to help patients with head injury, multiple sclerosis and epilepsy. In general, an organiser proved to be useful both as a reminder and as a text storage device, but for one patient who was densely amnesic and was living at home, the electronic aid proved to be of little benefit. Van den Broek et al. (2000) found that five memory-impaired patients who were provided with a voice organiser with message-alarm reminder functions had fewer memory lapses in two task settings—passing on a message they had been told nine hours earlier and remembering to carry out specified domestic chores. Kim et al. (2000) reported that most brain injured patients who had been trained to use a palm-top computer during their period of rehabilitation continued to use the device in everyday memory settings several years later. In a single-case study (Kim, Burke, Dowds, & George, 1999), one head injured patient who used this device as an in-patient, was better at remembering to attend therapy sessions and to take medication. Wright et al. (2001) noted that in a group of brain injured patients, high frequency users of organisers tended to prefer a standard keyboard organiser, whereas less frequent users preferred a more novel, penpad input system. In an earlier study involving elderly and younger participants from the general population, Wright et al. (2000) found most participants preferred keyboard data entry to touch-screen data entry, and generally made fewer errors using the keyboard modality.

SPEECH STORAGE DEVICES

As memory aids, speech recording devices are useful when long messages need to be stored. They are also helpful for memory disordered patients who have difficulty using an electronic organiser, possibly due to motor or visual impairment. As well as conventional tape recorders, digital "solid-state" recording devices have recently been introduced that can store up to several hours of speech. The attractive feature of these devices is the ability to store speech in discrete, labelled files which can be rapidly retrieved. Thus,

041-060.fm Page 47 Tuesday, February 17, 2004 11:40 AM

different categories of messages or things to do can be readily stored and accessed.

Some memory-impaired people complain of difficulty in remembering telephone messages, and a few devices are available which automatically tape telephone conversations. Users of such devices should be aware that they need to inform the caller that the conversation is being taped! A few digital voice recorders have alarm features that can be tagged to stored messages, thus enabling the device to be used as an event memory aid.

The main function of these devices is to act as temporary or permanent stores of knowledge. They are of benefit in educational settings such as listening to lectures, and are used for this purpose by many young patients with brain injury. Although at present they are not used as knowledge resources to the same extent as printed or visual electronic media, it is possible that in the future this may change with the enhanced storage and other features of recording devices.

ELECTRONIC COMMUNICATION DEVICES

Electronic communication devices can be classified into fixed devices, such as standard corded phones or free-standing devices such as cordless phones, mobile phones and pagers. Laptop and palm-top computers that can access the internet can also be classified as communication devices, and a number of mobile phones have additional functions similar to those found in electronic organisers and so can be used to send text messages or pictures. Here we focus on phone and paging systems for conveying verbal messages.

Telephones are available that allow storage and easy retrieval of frequently used numbers. Useful features can be found in most phones, e.g., visual display of a number while it is being dialled and the ability to identify the caller. Fixed phones are currently available in some countries with a "photophone" feature—the face of the person to be called can be represented on a button that is programmed with the person's number. Mobile phones and pagers are available with vibration cues instead of a ringing tone. These are useful for people with auditory impairments. Pagers have similar call-signalling facilities, and some pagers are available with in-built alarm features.

Fixed telephones, mobile phones and pagers have a variety of reminder systems associated with them. These range from in-built alarms/message-alarms, which may be pre-set or which can be set to signal at specified intervals or on a fixed date, through to alarm systems dependent on some other resource. Telephone-based reminding systems have in the past been shown to be useful in improving patient compliance with taking medication (Leirer, Morrow, Pariante, & Doksum, 1988; Leirer, Morrow, Tanke, & Pariante, 1991) or keeping appointments (Morrow et al., 1999). In recent years, pagers

041-060.fm Page 48 Tuesday, February 17, 2004 11:40 AM

have been employed to serve as more general reminder memory aids. Commercial paging companies in a number of countries offer reminder services, and a dedicated system for brain-injured patients has also been developed (Hersh & Treadgold, 1994; Wilson, Emslie, Quirk, & Evans, 2001; Wilson, Evans, Emslie, & Malinek, 1997). Phones can also be used to activate devices elsewhere, and thus may help in settings where the individual has to remember to turn on equipment such as domestic appliances.

Most phones have the capacity to store a large number of names and telephone numbers. Those which double-up as organisers have the usual text storage and retrieval facilities of the organisers outlined above. The ability of both fixed and mobile phones to link up to the internet has opened up a cornucopia of information resources that may act as knowledge memory aids.

Pagers can be useful as external memory aids, especially as reminders. Milch, Ziv, Evans, and Hillebrand (1996) found a paging system used in a hospice environment useful in improving compliance among residents in taking medication. In a single-case study, Aldrich (1998) used a dedicated paging system, NeuroPage, to help a head injured patient remember to carry out a range of activities, such as getting up and dressing, making lunch, watching the news headlines, feeding the cat, and taking his medication. The pager led to a significant improvement in performance of these activities. After NeuroPage was withdrawn, some improvement was maintained, but this was task dependent. Similar observations in a further single-case study with NeuroPage were made by Wilson, Emslie, Quirk, and Evans (1999). Wilson et al. (2001) carried out a large-scale study of 143 brain-damaged patients' use of NeuroPage. More than 80% of those who completed the 16-week trial were significantly more successful in carrying out everyday activities such as self-care, taking medication, and keeping appointments. For most patients, this improvement was maintained 7 weeks after returning the pager.

COMPUTER-BASED TECHNOLOGIES FOR KNOWLEDGE ACQUISITION AND UTILISATION

While the distinction between desktop computers, laptop computers, palmtop computers and personal organisers is becoming increasingly blurred as a result of advances in technology, in the following sections we mainly deal with those applications where desktop computers have been used in memory rehabilitation.

Exercises and drills

Although evidence for restoration of function using exercises and drills has not been positive, advances in computer technology and the ready availability of relatively inexpensive hardware have revived interest in such

041-060.fm Page 49 Tuesday, February 17, 2004 11:40 AM

methods (Bradley, Welch, & Skilbeck, 1993). The computer represents an ideal medium for presentation of repetitive exercises, and therapists have been attracted by the time-saving features of computer-delivered services. However, evidence of beneficial effects of memory exercises has not been forthcoming, whether they are delivered by computer or in the more traditional pencil-and-paper format (Skilbeck & Robertson, 1992). A study by Middleton, Lambert, and Seggar (1991), for example, found no specific effects of 32 hours of drill-oriented computer training of cognitive skills, including memory. Chen, Thomas, Glueckauf, and Bracy (1997) found no major differences across a range of neuropsychological measures between two groups of head injured patients, one that received computer-assisted cognitive rehabilitation and another that received more traditional rehabilitation. Skilbeck and Robertson (1992), in their review of computer techniques for the management of memory impairment, concluded that when appropriate controls are included in empirical studies, there is little evidence of positive outcome following computer drills.

Exercises and drills have not proved useful for restoring general memory ability. Nevertheless, repetitive practice is probably essential for memory-impaired patients to improve on any specific task or to learn any specific information, and computers may be a useful medium for the repeated presentation of such materials. Because learning does not appear to generalise beyond the training task, it is important that practice is directed towards something relevant or useful in everyday life. Repetitive practice of meaningless lists of numbers, letters, shapes, or locations plays no beneficial role in memory rehabilitation (Glisky & Glisky, 2002; Glisky & Schacter, 1989b; Wilson, 1991).

External aids

The personal computer has significant potential as an external aid for beneficial use by memory-impaired patients, although its capabilities have not been fully exploited (Ager, 1985; Harris, 1992). As an external aid, the computer has the power to act as a memory prosthesis, storing and producing on demand all kinds of information relevant to an individual's functioning in everyday life. It may also assist directly in the performance of tasks of daily living (see Cole & Dehdashti, 1990), acting as a reminder for activities such as taking medication or meals (Flannery, Butterbaugh, Rice, & Rice, 1997).

A series of successful studies employing microcomputers to assist memory-impaired people with tasks of daily living has been conducted by Kirsch and his colleagues (Kirsch, Levine, Fallon-Krueger, & Jaros, 1987; Kirsch, Levine, Lajiness-O'Neill, & Schnyder, 1992). These investigators used the computer as an "interactive task guidance system" providing a series of cues to guide patients through the sequential steps of real-world tasks such as

041-060.fm Page 50 Tuesday, February 17, 2004 11:40 AM

cookie baking and janitorial activities. In these studies, the computer acts solely as a compensatory device, providing the patient with step-by-step instructions for the performance of a task. Little knowledge of computer operation is required on the part of the subject, who merely responds with a single key-press to indicate that the instructions have been followed.

Another promising line of research was conducted by Cole and colleagues (Cole & Dehdashti, 1990; Cole, Dehdashti, Petti, & Angert, 1993). They designed highly customised computer interventions for brain-injured patients with a variety of cognitive deficits (see also Cole, Dehdashti, Petti, & Angert, 1988). Each intervention tried to help patients perform an activity of daily living they were able to accomplish prior to trauma but were now unable to perform without assistance. For example, a patient with severe memory and attentional deficits was able to use a customised text editor and software to construct things-to-do lists, take notes during telephone conversations, and to carry out home financial transactions (cheque writing, deposits, withdrawals, mailings, etc.), activities that had become impossible since her injury. In this case, the computer was modified to simplify these tasks and to bypass the particular cognitive deficits that were problematic for the patient.

Memory-impaired patients have been able to learn how to use computers as word-processors. For example, Batt and Lounsbury (1990) constructed a simple flowchart with coloured symbols and simple wording that enabled a memory-impaired patient to use a word-processing package. The bypassing of confusing menus and the reduction of memory load, enabled the patient to carry out the appropriate word-processing steps without difficulty and to operate the computer by himself (see also Glisky, 1995; Hunkin & Parkin, 1995; Van der Linden & Coyette, 1995).

In all of these studies, memory-impaired people used the computer to support some important activity of daily life. Hardware and software were modified so that problems were eliminated or reduced and only a few simple responses needed to be learned. The computer essentially served a prosthetic function, allowing brain injured patients to perform activities that were otherwise impossible. These kinds of intervention require no assumptions concerning adaptation of the neural or cognitive mechanisms involved in memory, and in general they make no claims concerning restoration or changes in underlying mnemonic ability. Frequently, however, increases in self-confidence and self-esteem are observed in patients following successful computer experience (Batt & Lounsbury, 1990; Cole et al., 1993; Glisky & Schacter, 1987; Johnson, 1990). Whether these psychosocial changes are specifically attributable to computer use, as opposed to other non-specific features of training, has not been empirically documented.

In the past one of the negative features of these interventions, from a clinical perspective, has been their high cost and limited applicability. Design of customised systems has required time, money and expertise and

041-060.fm Page 51 Tuesday, February 17, 2004 11:40 AM

each design may have been useful for a single patient. With continued development in this area, however, prototypical systems are becoming available that might serve a broader range of patients and be easily administered in the clinic, such as the automated reminder system developed by Mihailidis, Fernie, and Barbenel (2001). Some of these developments are considered elsewhere in this special issue (see, for example, the paper by Mihailidis et al.).

Acquisition of domain-specific knowledge

In an effort to capitalise on the preserved memory abilities of amnesic patients, Glisky, Schacter, and Tulving (1986) devised a fading of cues technique, called the method of vanishing cues, which was designed to take advantage of patients' normal responses to partial cues to teach them complex knowledge and skills that might be used in everyday life. The training technique provides as much cue information as patients need to make a correct response and then gradually withdraws it across learning trials. The microcomputer serves essentially the role of teacher, presenting information and feedback in a consistent fashion, controlling the amount of cue information in accordance with patients' needs and prior responses, and allowing people to work independently at their own pace. Unlike interventions in which the computer is provided as a continuing prosthetic support, the goal of these interventions is to teach people the information that they need in order to function without external support (see Glisky, 1992b).

Using the method of vanishing cues, Glisky and colleagues successfully taught memory-impaired patients information associated with the operation of a microcomputer, and a number of vocational tasks including computer data-entry, microfilming, database management and word-processing (see Glisky & Glisky 2002, for discussion).

There are, however, some caveats concerning the domain-specific learning approach. Although memory-impaired patients are able to learn considerable amounts of complex information, their learning may be exceedingly slow and may result in knowledge representations that are different from those of the general population. In particular, patients cannot always access newly acquired knowledge on demand or use it flexibly in novel situations. In other words, transfer beyond the training context cannot be assumed (Wilson, 1992), although it has been demonstrated under some conditions (Glisky, 1995; Glisky & Schacter, 1989a). It is therefore essential that all information relevant to the performance of a particular functional task be taught directly so that the need for generalisation is minimal (Glisky, Schacter, & Butters, 1994).

The vanishing cues methodology was designed to capitalise on preserved abilities of amnesic patients in order to teach them knowledge and skills relevant in everyday life. Use of intact memory processes to compensate for

041-060.fm Page 52 Tuesday, February 17, 2004 11:40 AM

those that have been disrupted or lost has often been suggested as an appropriate strategy for rehabilitation (Baddeley, 1992; Salmon & Butters, 1987); yet, as Baddeley has pointed out, few interventions of this type, other than the one used by Glisky and colleagues, have been attempted. It is likely that we still lack sufficient knowledge concerning the nature of the processes preserved in amnesia to take optimal advantage of them in rehabilitation. Nevertheless, this approach seems to be a promising one that may gain momentum as basic research provides additional information concerning processes and structures involved in normal memory.

Vocational tasks

One area in which computers might serve a potentially important function is the workplace. Glisky (1992a, 1992b) has suggested that some vocational tasks requiring the use of a computer may present good opportunities for employment for memory-impaired patients for a number of reasons. First, patients are capable of procedural learning; they can acquire a fixed set of procedures such as those required for data-entry or word-processing, and apply them in a consistent fashion over time. Second, computers in general require rather rigid adherence to a set of rules and can be counted on to be highly consistent, unlike their human counterparts. Once patients have learned the rules and their applications, they are less likely to be called upon to make online decisions or respond to novel circumstances. Third, many computer tasks lend themselves rather well to laboratory simulations so that job training can be accomplished before patients enter the workplace. Glisky and colleagues have found that careful step-by-step training in the laboratory of all components of a task facilitates transfer to the real-world environment and allows the patient to enter the workplace with a high degree of confidence and skill (Glisky & Schacter, 1989a).

In general, computer jobs have been overlooked by rehabilitation and vocational specialists perhaps because they seem too high-tech and complex and, therefore, beyond the capabilities of brain injured patients. Yet, even patients with quite severe memory impairments have been able to acquire the knowledge and skills needed to perform computer data-entry and word-processing tasks (Glisky, 1992a, 1995). It is worth keeping in mind, however, that all aspects of a task need to be taught explicitly and directly in order to minimise problems in generalisation. Although transfer of work skills across changes in materials (Glisky, 1992a) and from a training to a work or home environment has been demonstrated (Glisky, 1995; Glisky & Schacter, 1989a), changes in the actual procedures may present serious difficulties.

Another use of computers involves virtual reality technology. As this is dealt with by Rizzo, Schultheis, Kerns, and Mateer, (2004 this issue) we will not discuss it further here.

041-060.fm Page 53 Tuesday, February 17, 2004 11:40 AM

THE APPLICATION OF MEMORY AIDS IN REHABILITATION SETTINGS

Factors to be considered in the use of memory aids in rehabilitation include general ones applicable to most forms of neuropsychological intervention and memory rehabilitation, and specific ones relating to the particular use of aids to overcome memory difficulties—a form of "compensatory memory training". In a critical review covering a number of areas of cognitive rehabilitation, Cicerone et al. (2000) offered useful guidelines that are relevant for the use of memory aids. They "found evidence for the effectiveness of compensatory memory training for subjects with mild memory impairments compelling enough to recommend it as a Practice Standard. The evidence also suggests that memory remediation is most effective when subjects are fairly independent in daily function, are actively involved in identifying the memory problems to be treated, and are capable and motivated to continue active, independent strategy use" (Cicerone et al., 2000, p. 1605).

General factors

For any intervention to be effective and to be seen to be effective, some criteria need to be satisfied. These include:

1. The intervention needs to bring about meaningful changes in the patient's everyday memory functioning. How one defines "meaningful change" may vary from patient to patient, but the patient should be able to carry out more memory-related activities, with greater ease and success, and with less distress, than before the intervention.
2. The improvement in memory functioning should be permanent.
3. The improvement should have minimal side-effects.
4. The intervention should be cost-effective, both in terms of money and time.
5. The intervention should be easy to administer by a third party.
6. The treatment should be applicable to a large number of patients, ideally across disease categories and severity of memory loss.
7. The intervention should be beneficial over and above any general "placebo" or incidental effects resulting from the treatment.

In individual patients, variables worth considering are:

1. Age, educational level, and premorbid knowledge and skills.
2. Any physical disability, such as sensory or motor loss.
3. The intactness or otherwise of non-memory cognitive functions.
4. Supportive and possible negative influences that the family/carer may bring to bear on the therapeutic programme.

041-060.fm Page 54 Tuesday, February 17, 2004 11:40 AM

5. Current daily routine and the demands which this places on memory. Many memory functions, and in particular prospective memory, are better earlier than later in the day (Wilkins & Baddeley, 1978).
6. Any behavioural, attentional or motivational problems. On the one hand, memory aids may act as motivational cues to help with problems such as apathy, but the use of memory aids often requires some involvement of executive functions such as initiation of behaviour, planning/organisational skills, problem solving ability, focused attention, etc.

The severity and pattern of memory loss is a major factor, and it is important to pay particular attention to a number of areas:

1. Everyday memory symptoms as reported by the patient and by an informed observer, noting the patient's insight and concern about his memory difficulties.
2. Severity and pattern of anterograde memory loss.
3. Severity and pattern of retrograde memory loss, in particular the extent to which past knowledge and skills have been lost.
4. The extent to which new skill learning and implicit memory are preserved.

Specific factors

There are a number of specific factors to be borne in mind when considering whether to encourage and train patients in the use of memory aids to help everyday memory.

1. How often and which type of memory aid has been used in the past? For example, many elderly people are accustomed to using simple diaries and are reluctant to change to electronic devices, no matter how much more effective they may be. Some patients need to be reassured that using memory aids will not lead to their becoming lazy or their brain wasting away through lack of use. They need to be reassured that using memory aids with other people around is nothing to be ashamed of, perhaps pointing out that such aids are used increasingly by the general population. Memory aids can be seen as status symbols and may enhance the self-esteem of memory-impaired people.
2. Although it is the principal duty of the clinician to find a memory aid simple to use and suitable for a particular patient, the patient should, if possible, be given a choice and be involved in any decisions.
3. A carer/relative needs to be closely involved in the process from the beginning so as to encourage the use of the aid in domestic settings. In particular, if the aid is complicated to use, this person also needs to be taught to use it so that there is someone to turn to if problems arise in operating the aid.

041-060.fm Page 55 Tuesday, February 17, 2004 11:40 AM

4. Memory aids are often given to patients to use with little further or no intervention from the therapist. If only life were this simple. As Intons-Peterson and Newsome (1992) have pointed out, there are a number of cognitive processes involved in the use of even simple external memory aids. Thus, memory-impaired people need to be trained in the "metamemory" skill of being able to identify situations where a memory aid will be useful, they must motivate themselves to use a memory aid, choose an aid that will be useful for the particular circumstances, and remember how to operate and use the memory aid effectively.
5. Memory-impaired people should be motivated both to learn to use the aid, and to adapt daily routines and habits so as to incorporate the memory aid into such activities. Ideally, they should formulate some of the reminders so that they are seen as self-cues rather than "nagging" from some external source.

For more complex aids such as electronic organisers, a specific training programme should be designed in which stages of learning a particular procedure are broken down into steps. Principles such as spaced rehearsal, graded reduction of support/vanishing cues and error-free learning, feedback and encouragement, and help-cards may be required in the teaching process. The training programme in the clinic should, as closely as feasible, mimic everyday uses of the memory aid, with concrete examples being drawn from the patient's daily routine. Training in the use of electronic organisers usually requires four to six sessions, and if these are provided weekly, homework can be set for the patient. The beginning of a therapy session can test long-term retention of what was learned in an earlier session. Finally, many effective interventions involve a particular combination of environmental, stationery, mechanical, and electronic memory aids, as in the case described by Wilson (1999). The challenge lies with the clinician to use his/her knowledge and experience to suggest and draw up a particular combination of teaching strategies.

An interesting and recent paper by Reason (2002) describes the criteria of good reminders and how these might be used to reduce errors. Although written for people without neurological impairment, Reason's ideas could also apply to the field of memory rehabilitation.

CONCLUSIONS AND FUTURE DEVELOPMENTS

External memory aids are effective in improving everyday memory functioning, and this benefit is particularly evident in the area of prospective memory. Computer-related memory rehabilitation strategies remain largely task-specific in their benefit, but may be useful to the extent that they

041-060.fm Page 56 Tuesday, February 17, 2004 11:40 AM

perform similar functions to external memory aids. The use of environmental cues, either to help navigational memory or to enhance man–machine interaction, is another area which is potentially beneficial to people with memory deficits.

While technological innovations may drive many of the developments in memory rehabilitation, advances in conceptual and clinical spheres are equally important. We do not have a comprehensive conceptual framework to consider the various strategies used to enhance memory functioning. If conceptual and empirical links could be made with other attempts to improve memory functioning, such as pharmacological agents and neural implants, rehabilitation might move forwards, especially if these attempts could be integrated into a theoretical framework that accounts for neural plasticity and recovery of memory function following neurological disease or injury (Robertson & Murre, 1999). In the clinical sphere, there may be a greater refinement in our understanding of which patients will benefit most from memory aids. Ideally, a patient's clinical and neuropsychological profile, together with factors such as specific memory needs should be matched to the features of potential memory aids to inform the clinician of the particular memory aids, or combination of treatments, that will be of maximum benefit to the individual. Careful evaluation of the effectiveness of memory aids will require further advances in memory assessment procedures, in particular those which can reliably assess everyday memory functioning (see Glisky & Glisky, 2002). The cost-effectiveness of memory aids needs to be considered, especially where computer-based aids or expensive electronic devices may perform functions that can be carried out by stationery memory aids or by less expensive electronic memory aids. Advances in technology may allow for the introduction of more sophisticated, cheaper and more user-friendly aids, and some memory aids may emerge that have been purpose-built for memory-impaired individuals. Future developments in external memory aids include:

1. The integration of multiple memory-related functions within a single electronic unit, which will carry out tasks currently performed by devices such as a personal organiser, mobile phone, e-mail/internet facility, reminder/pager, etc.
2. Devices, such as electronic organisers, that more readily accept hand-written input via an adjacent note-pad which permits infrared transfer of impressions made on paper.
3. Memory pens which keep a record of what has been written and which allow this information to be transferred to another storage medium.
4. Reminders that have context-sensitive features, such that a message-alarm will activate when the individual engages in a related activity, or when other critical people are in the vicinity (Lamming et al., 1994).

041-060.fm Page 57 Tuesday, February 17, 2004 11:40 AM

5. Reminders that include a "task enactment-alarm" link, such that the alarm only turns off when the target activity has been carried out (cf. Azrin & Powell, 1969).
6. Wearable memory aids that integrate more naturally with the dress, habits and routines of patients (cf. Hoisko, 2000).
7. Devices that use wireless (such as the new "bluetooth") technology to convey information about the location of items.

It is too early to say which, if any, of these developments will have a major impact on the application of memory aids in clinical settings. If conceptual, empirical, biological and technological advances across disciplines are harnessed and harmonised in meaningful ways, and if clinicians and researchers focus their attention and resources on the application of resultant devices in clinical settings, there will be undoubted benefits for memory-impaired neurological patients in the years to come.

REFERENCES

Ager, A. (1985). Recent developments in the use of microcomputers in the field of mental handicap: Implications for psychological practice. *Bulletin of the British Psychological Society*, *38*, 142–145.

Aldrich, F. K. (1998). Pager messages as self reminders: A case study of their use in memory impairment. *Personal Technologies*, *2*, 1–10.

Azrin, N., & Powell, J. (1969). Behavioural engineering: The use of response priming to improve prescribed medication. *Journal of Applied Behaviour Analysis*, *2*, 39–42.

Baddeley, A. D. (1992). Implicit memory and errorless learning: A link between cognitive theory and neuropsychological rehabilitation? In L. R. Squire, & N. Butters (Eds.), *Neuropsychology of memory* (2nd ed., pp. 309–314). New York: Guilford Press.

Batt, R. C., & Lounsbury, P. A. (1990). Teaching the patient with cognitive deficits to use a computer. *American Journal of Occupational Therapy*, *44*, 364–367.

Bradley, V. A., Welch, J. L., & Skilbeck, C.E. (1993). *Cognitive retraining using microcomputers*. Hove, UK: Lawrence Erlbaum Associates Ltd.

Chen, S., Thomas, J., Glueckauf, R., & Bracy, O. (1997). The effectiveness of computer-assisted cognitive rehabilitation for persons with traumatic brain injury. *Brain Injury*, *11*, 197–209.

Cicerone, K., Dalhberg, C., Kalmar, K., Langenbahn, D., Malec, J., Bergquist, T., Felicetti, T., Giacino, J., Harley, J., Harrington, D., Herzog, J., Kneipp, S., Laatsch, L., & Morse, P. (2000). Evidence-based cognitive rehabilitation: Recommendations for clinical practice. *Archives of Physical Medicine and Rehabilitation*, *81*, 1596–1615.

Cole, E., & Dehdashti, P. (1990). Interface design as a prosthesis for an individual with a brain injury. *SIGCHI Bulletin*, *22*, 28–32.

Cole, E., Dehdashti, P., Petti, L., & Angert, M. (1988). Prosthesis Ware: A new class of software supports the activities of daily living. *Neuropsychology*, *2*, 41–57.

Cole, E., Dehdashti, P., Petti, L., & Angert, M. (1993). Design parameters and outcomes for cognitive prosthetic software with brain injury patients. *Proceedings of the RESNA International '93 Conference*, *13*, Arlington, VA: RESNA Press.

Flannery, M., Butterbaugh, G., Rice, D., & Rice, J. (1997). Reminding technology for prospective memory disability: A case study. *Pediatric Rehabilitation*, *1*, 239–244.

041-060.fm Page 58 Tuesday, February 17, 2004 11:40 AM

Fowler, R. S., Hart, J., & Sheehan, M. (1972). A prosthetic memory: An application of the prosthetic environment concept. *Rehabilitation Counselling Bulletin*, *16*, 80–85.

Giles, G. M., & Shore, M. (1989). The effectiveness of an electronic memory aid for a memory-impaired adult of normal intelligence. *American Journal of Occupational Therapy*, *43*, 409–411.

Glisky, E. L. (1992a). Acquisition and transfer of declarative and procedural knowledge by memory-impaired patients: A computer data-entry task. *Neuropsychologia*, *30*, 899–910.

Glisky, E. L. (1992b). Computer-assisted instruction for patients with traumatic brain injury: Teaching of domain-specific knowledge. *Journal of Head Trauma Rehabilitation*, *7*, 1–12.

Glisky, E. L. (1995). Acquisition and transfer of word processing skill by an amnesic patient *Neuropsychological Rehabilitation*, *5*, 299–318.

Glisky, E. L., & Glisky, M. L. (1999). Memory rehabilitation in the elderly. In D. Stuss, G. Winocur, & I. Robertson (Eds.), *Cognitive neurorehabilitation* (pp. 347–361). Cambridge: Cambridge University Press.

Glisky, E. L., & Schacter, D. L. (1987). Acquisition of domain-specific knowledge in organic amnesia: Training for computer-related work. *Neuropsychologia*, *25*, 893–906.

Glisky, E. L., & Schacter, D. L. (1989a). Extending the limits of complex learning in organic amnesia: Computer training in a vocational domain. *Neuropsychologia*, *27*, 107–120.

Glisky, E. L., & Schacter, D. L. (1989b). Models and methods of memory rehabilitation. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (pp. 233–246). Amsterdam: Elsevier.

Glisky, E. L., Schacter, D. L., & Butters, M. A. (1994). Domain-specific learning and memory remediation. In M. J. Riddoch, & G. W. Humphreys (Eds.), *Cognitive neuropsychology and cognitive rehabilitation* (pp. 527–548). Hove, UK: Lawrence Erlbaum Associates Ltd.

Glisky, E. L., Schacter, D. L., & Tulving, E. (1986). Learning and retention of computer-related vocabulary in amnesic patients: Method of vanishing cues. *Journal of Clinical and Experimental Neuropsychology*, *8*, 292–312.

Harris, J. E. (1992). Ways of improving memory. In B. A. Wilson, & N. Moffat (Eds.), *Clinical management of memory problems* (2nd ed., pp. 59–85). London: Chapman and Hall.

Herrmann, D., Brubaker, B., Yoder, C., Sheets, V., & Tio, A. (1999). Devices that remind. In F. Durso, R. Nickerson, R. Schvaneveldt, S. Dumais, D. Lindsay, & M. Chi (Eds.), *Handbook of applied cognition* (pp. 377–407). Chichester, UK: John Wiley.

Hersh, N., & Treadgold, L. (1994). NeuroPage: The rehabilitation of memory dysfunction by prosthetic memory and cueing. *Neurorehabilitation*, *4*, 187–197.

Hoisko, J. (2000). Context triggered visual episodic memory prosthesis. In *Proceedings of the Fourth International Symposium on Wearable Computers* (pp. 185–186). Atlanta, Georgia: IEEE Computer Society.

Hunkin, N. M., & Parkin, A. J. (1995). The method of vanishing cues: An evaluation of its effectiveness in teaching memory-impaired individuals. *Neuropsychologia*, *33*, 1255–1279.

Intons-Peterson, M. J., & Newsome, G. L., III (1992). External memory aids: Effects and effectiveness. In D. J. Herrmann, H. Weingartner, A. Searleman, & C. McEvoy (Eds.), *Memory improvement: Implications for memory theory* (pp. 101–121). New York: Springer-Verlag.

Johnson, R. (1990). Modifying memory function: Use of a computer to train mnemonic skill. *British Journal of Clinical Psychology*, *29*, 437–438.

Kapur, N. (1995). Memory aids in the rehabilitation of memory disordered patients. In A. D. Baddeley, B. A. Wilson, & F. N. Watts (Eds.), *Handbook of memory disorders* (pp. 535–557). Chichester, UK: John Wiley.

Kapur, N., Glisky, E. L., & Wilson, B. A. (2002). External memory aids and computers in memory rehabilitation. In A. D. Baddeley, M. D. Kopelman, & B. A. Wilson (Eds.), *Handbook of memory disorders* (2nd ed.). Chichester, UK: John Wiley.

041-060.fm Page 59 Tuesday, February 17, 2004 11:40 AM

Kim, H. J., Burke, D. T., Dowds, M. M., & George, J. (1999). Utility of a microcomputer as an external memory aid for memory-impaired head injury patient during in-patient rehabilitation. *Brain Injury*, *13*, 147–150.

Kim, H. J., Burke, D. T., Dowds, M. M., Robinson Boone, K. A., & Parks, G. J. (2000). Electronic memory aids for outpatient brain injury: Follow-up findings. *Brain Injury*, *14*, 187–196.

Kirsch, N. L., Levine, S. P., Fallon-Krueger, M., & Jaros, L. A. (1987). The microcomputer as an "orthotic" device for patients with cognitive deficits. *Journal of Head Trauma Rehabilitation*, *2*, 77–86.

Kirsch, N. L., Levine, S. P., Lajiness-O'Neill, R., & Schnyder, M. (1992). Computer-assisted interactive task guidance: Facilitating the performance of a simulated vocational task. *Journal of Head Trauma Rehabilitation*, *7*, 13–25.

Lamming, M., Brown, P., Carter, K., Eldridge, M., Flynn, M., Louie, G., Robinson, P., & Sellen, A. (1994). The design of a human memory prosthesis. *The Computer Journal*, *37*, 153–163.

Leirer, V., Morrow. D., Pariante, G., & Doksum, T. (1988). Increasing influenza vaccination adherence through voice mail. *Journal of the American Geriatric Society*, *37*, 1147–1150.

Leirer, V., Morrow, D., Tanke, E., & Pariante, G., (1991). Elders' nonadherence: Its assessment and medication reminding by voice mail. *The Gerontologist*, *31*, 514–520.

Middleton, D. K., Lambert, M. J., & Seggar, L. B. (1991). Neuropsychological rehabilitation: Microcomputer-assisted treatment of brain-injured adults. *Perceptual and Motor Skills*, *72*, 527–530.

Mihailidis, A., Fernie, G., & Barbenel, J. (2001). The use of artificial intelligence in the design of an intelligent cognitive orthosis for people with dementia. *Assistive Technology*, *13*, 23–39.

Milch, R., Ziv, L., Evans, V., & Hillebrand, M. (1996). The effect of an alphanumeric paging system on patient compliance with medicinal regimens. *American Journal of Hospital and Palliative Care*, *13*, 46–48.

Morrow, D., Leirer, V., Carver, L., Tanke, E., & McNally, A. (1999). Repetition improves older and younger adult memory for automated appointment messages. *Human Factors*, *41*, 194–204.

Naugle, R., Naugle, C., Prevey, M., & Delaney, R. (1988). New digital watch as a compensatory device for memory dysfunction. *Cognitive Rehabilitation*, *6*, 22–23.

Nielsen, J. (1958). *Memory and amnesia*. Los Angeles: San Lucas Press.

Reason, J. (1990). *Human error*. Cambridge: Cambridge University Press.

Reason, J. (2002). Combating omission errors through task analysis and good reminders. *Quality Safe Health Care*, *11*, 40–44.

Rizzo, A. A., Schultheis, M. Kerns, K. A., & Mateer, C. (2004). Analysis of assets for virtual reality applications in neuropsychology. *Neuropsychological Rehabilitation*, *14*(1/2), 207–239.

Robertson, I. H., & Murre, J. (1999). Rehabilitation of brain damage: Brain plasticity and principles of guided recovery. *Psychological Bulletin*, *125*, 544–575.

Salmon, D. P., & Butters, N. (1987). Recent developments in learning and memory: Implications for the rehabilitation of the amnesic patient. In M. J. Meier, A. L. Benton, & L. Diller (Eds.), *Neuropsychological rehabilitation* (pp. 280–293). New York: Guilford.

Schacter, D. L. (2001). *The seven sins of memory*. Boston: Houghton Miffin Company.

Skilbeck, C., & Robertson, I. (1992). Computer assistance in the management of memory and cognitive impairment. In B. A. Wilson & N. Moffat (Eds.), *Clinical management of memory problems* (2nd ed., pp. 154–188). London: Chapman and Hall.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381–403). New York: Academic Press.

Tulving, E. (2000). Concepts of memory. In E. Tulving & F. Craik (Eds.), *The Oxford handbook of memory* (pp. 33–43). New York: Oxford University Press.

041-060.fm Page 60 Tuesday, February 17, 2004 11:40 AM

Van den Broek, M. D., Downes, J., Johnson, Z., Dayus, B., & Hilton, N. (2000). Evaluation of an electronic memory aid in the neuropsychological rehabilitation of prospective memory deficits. *Brain Injury*, *14*, 455–462.

Van der Linden, M., & Coyette, F. (1995). Acquisition of word processing knowledge in an amnesic patient: Implications for theory and rehabilitation. In R. Campbell & M. A. Conway (Eds.), *Broken Memories* (pp. 54–76). Oxford: Blackwell.

Warrington, E. K. (1986). Memory for facts and memory for events. *British Journal of Clinical Psychology*, *25*, 1–12.

Wilkins, A. J., & Baddeley, A. D. (1978). Remembering to recall in everyday life: An approach to absentmindedess. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory* (pp. 27–34). London: Academic Press.

Wilson, B. A. (1991). Theory, assessment, and treatment in neuropsychological rehabilitation. *Neuropsychology*, *5*, 281–291.

Wilson, B. A. (1992). Memory therapy in practice. In B. A. Wilson & N. Moffat (Eds.), *Clinical management of memory problems* (2nd ed., pp. 120–153). London: Chapman and Hall.

Wilson, B. A (1999). *Case studies in neuropsychological rehabilitation* (ch. 4). Oxford: Oxford University Press.

Wilson, B. A., Emslie, H. C., Quirk, K., & Evans, J. (1999). George: Learning to live independently with NeuroPage. *Rehabilitation Psychology*, *44*, 284–296.

Wilson, B. A., Emslie, H. C., Quirk, K., & Evans, J. (2001). Reducing everyday memory and planning problems by means of a paging system: A randomised control crossover study. *Journal of Neurology, Neurosurgery and Psychiatry*, *70*, 477–482.

Wilson, B. A., Evans, J., Emslie, H., & Malinek, V. (1997). Evaluation of NeuroPage: A new memory aid. *Journal of Neurology, Neurosurgery and Psychiatry*, *63*, 113–115.

Wilson, B. A., & Watson, P (1996). A practical framework for understanding compensatory behaviour in people with organic memory impairment. *Memory*, *4*, 465–486.

Wright, P., Bartram, C., Rogers, N., Emslie, H., Evans, J., Wilson, B. A., & Belt, S. (2000). Text entry on handheld computers by older users. *Ergonomics*, *43*, 702–716.

Wright, P., Rogers, N., Hall, C., Wilson, B. A., Evans, J., Emslie, H., & Bartram, C. (2001). Comparison of pocket-computer memory aids for people with brain injury. *Brain Injury*, *15*, 787–800.